Greenhouse Gas Emissions
from Transportation Options

Transportation is the leading source of total GHG emissions

According to official Canadian statistics (2004), the transportation sector is responsible for 31% of all energy-related GHG emissions. This statistic is misleading, however, because it takes account of direct tailpipe emissions only. A more rigorous estimate should include the activities supporting transportation, many of which generate high emissions, such as oil refining; the petrochemical plants and smelters that are essential for car manufacturing; and the steel and concrete required for infrastructures such as roads and bridges. Moreover, leaking HFCs from vehicles' air conditioning units contribute greatly to global warming. When we consider these "indirect" emissions (Table 1), the transportation sector is responsible for about 50% of Canadian energy-related emissions.

Table 1: Estimates of direct and indirect GHG emissions from the transportation sector

Type of assessment	Activity	Cumulative % of total GHG emissions	
		Québec	Canada
Direct tailpipe emissions	Fuel combustion in vehicles	38 %	31 %
Production life cycle	- Fuel production: + 25% of direct emissions - Vehicle manufacturing: + 14% of direct emissions	54 %	44 %
Air conditioning units	- For a recent car, average HFC leakage of 220 g per vehicle/year (much more for older cars)	57 %	47 %
Vehicle maintenance	- Garages - Production of lubricants, antifreeze, etc.	58 %	48 %
Road network	- Cement and asphalt - Various metals for roads, bridges and lamp posts - Electricity for highway lighting	62 %	52 %
Low-density sprawl	Cities designed around cars have low density, with increased infrastructure requirements: sewers, water, utilities, streetlights, etc.	not quantifiable	not quantifiable

Note: Estimates based on 2004 data

Other environmental impacts of transportation

The main topic of this fact sheet is greenhouse gas emissions (mainly CO_2), responsible for climate change. Another important issue is smog, which affects respiratory health. Transportation activities are responsible for over 50% of anthropogenic emissions of fine particulates, roughly 60% of nitrogen oxides (NO_x) and 30% of volatile organic compounds (VOC), all smog-causing pollutants. (These statistics do not include indirect emissions.)

Road networks also have major effects on many ecosystems. Vehicles accidentally kill a large number of animals:

- In Quebec, each year, about 5,000 deer are killed on the road and about 500 moose.
- In the United States, the annual road kill is estimated at about 400 million mammals, birds and reptiles.

Human fatalities due to car accidents must also be considered: each year, more than 50,000 deaths in North America.

Performance of passenger transportation modes

Modal choice can be a tool for reducing GHG emissions. Figures A and B compare the efficiency of various transportation modes, in kilojoules **for each kilometre travelled by one passenger.** (For more detailed information on this issue, see Table 3 at the end of this fact sheet.)

Figure A: Efficiency of passenger transport modes – Intercity travel

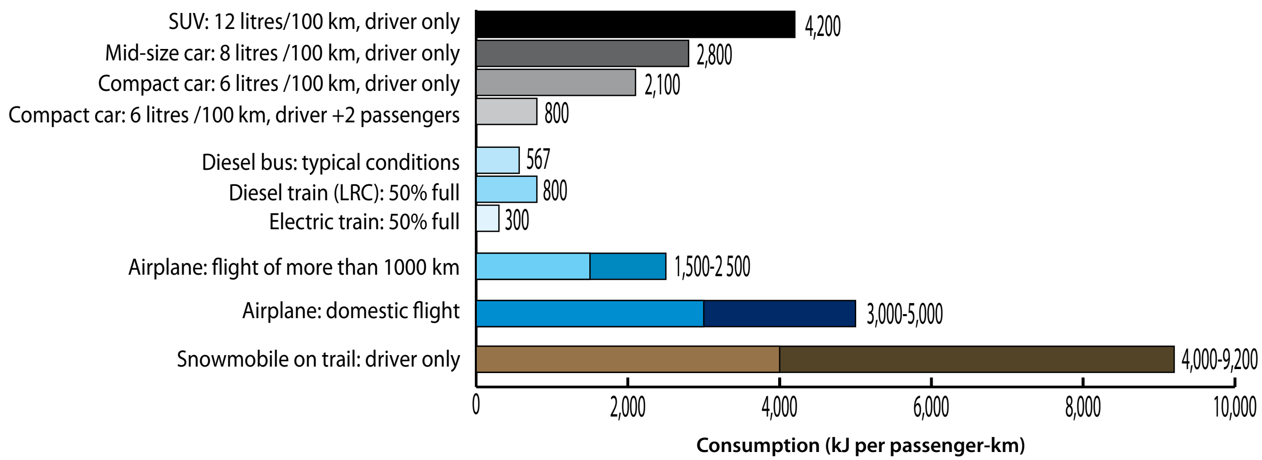
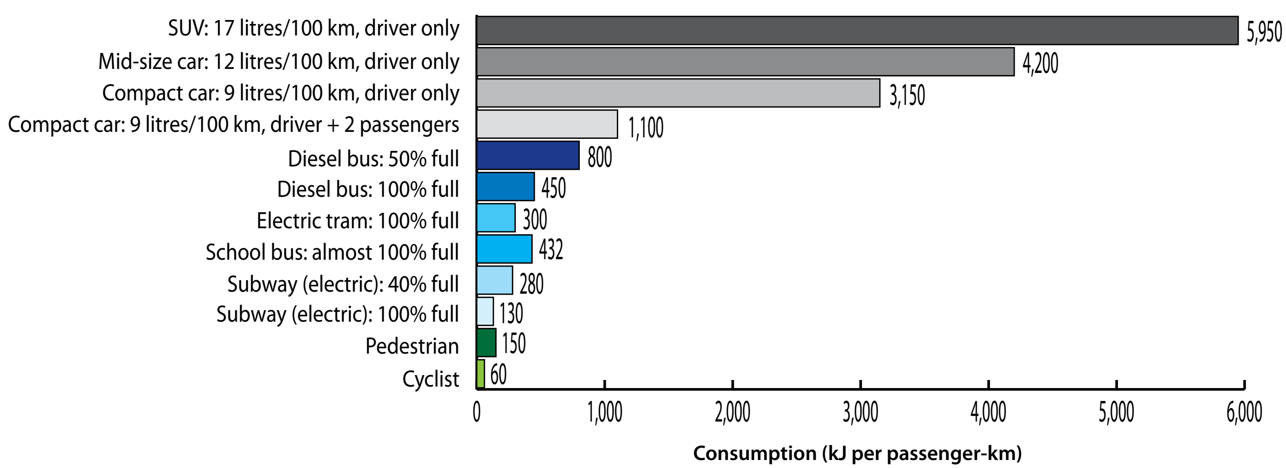


Figure B: Efficiency of passenger transport modes – Urban travel



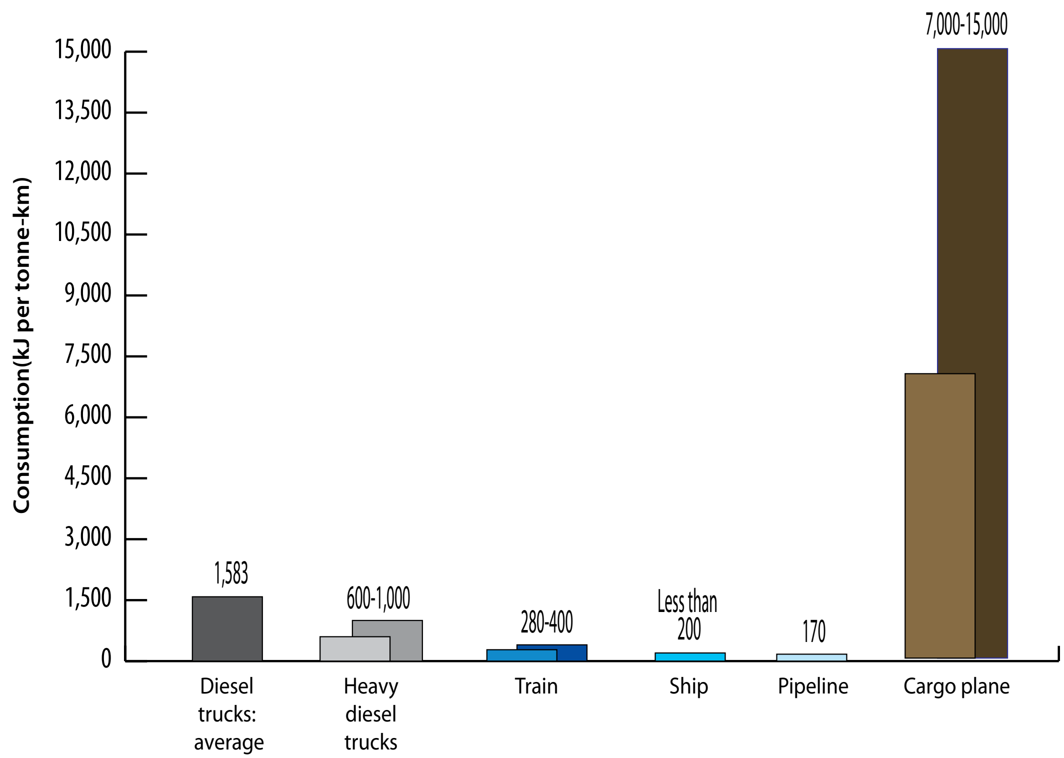
Main findings, for each kilometre travelled per passenger.

- A large sport utility vehicle (SUV) consumes about twice as much energy as a compact or sub-compact car.
- For intercity transportation, the energy efficiency of trains and buses is roughly the same.
- For distances such as Montréal–Québec or Montréal–Toronto, an airplane may consume 10 times as much energy as a bus or a train.
- In urban conditions, the driver (alone) of a compact car may consume four times as much energy as a passenger on a bus filled at 50% capacity.
- During rush hour, the driver (alone) of a large SUV consumes 45 times as much energy as a subway passenger.
- Direct electrification (by overhead line or subway rail) can double or even triple the energy efficiency of public transit.

Performance of freight transportation modes

Figure C compares the efficiency of various freight transportation modes, in kilojoules **for each tonne transported over a kilometre.**

Figure C: Efficiency of freight transportation modes, for typical load factors



Main findings per tonne of freight

- Shipping freight by water or rail consumes three to seven times less energy than by truck.
- Shipping by air is extremely inefficient, with energy consumption 30 to 70 times greater than by water.

Transportation trends

What were the major trends of the last two decades?
- Greater market penetration of many large vehicles, such as SUVs and minivans
- Substantial increases in use of air cargo and truck freight
- Declining use of trains and buses

When these trends are linked with the performance figures shown in figures A, B and C, it is easy to explain the overall growth in GHG emissions from the transportation sector.

The performance of new technologies

Given the growing emissions from transportation, many are counting on new technologies to reduce GHG emissions from the sector. Among these, hybrid electric vehicles are already available and reliable. Over the longer term, many research dollars are being spent on hydrogen fuel cells. This technology has raised very high expectations in terms of reducing GHG emissions, due to the fact that fuel cells produce electricity from hydrogen, with water vapor as the only by-product. This technology does indeed appear to be very clean. This is an illusion, however, because hydrogen is not naturally available on earth and, to produce it, much more energy must be expended than the energy finally obtained in the hydrogen fuel.

Consequently, hydrogen is not a net source of energy, but simply a vector for distributing other sources of energy. Currently, the only cost-effective method of producing hydrogen is from natural gas (CH_4). This method's efficiency and the resulting emissions have been studied extensively.

Table 2 presents a summary of the results of three international life cycle assessments of the GHG emissions from various automotive technologies. They lead to the following conclusions:

- When the energy source is natural gas, fuel cell systems emit as many GHG emissions as simply burning the natural gas, which is a much simpler, more reliable and cheaper option.
- The hybrid electric design allows GHG reductions of about 45% , compared with a conventional engine of similar power. This technology is commercially available now, unlike fuel cells.
- Battery-powered electric vehicles have the best environmental performance, even when the electricity is generated by combined-cycle gas turbines (fueled by natural gas).

Table 2: Life cycle assessment of GHG emissions from various automotive technologies

Automotive technology (cars of similar size and power)	Energy source	GHG emissions compared with those from a conventional vehicle
Conventional car and engine	Gasoline	Base
Hybrid electric vehicle	Gasoline	Reduction of 41–46%
Conventional car and engine	Natural gas	Reduction of 26–35%
Hybrid electric vehicle	Natural gas	Reduction of 54%
Fuel cell, gas ➔ hydrogen conversion	Natural gas	Reduction of 25–40%
Battery-powered electric vehicle, electricity from combined-cycle gas turbines	Natural gas	Reduction of 60–68%

The controversy over the performance of hybrid electric vehicles

Many technical studies report major efficiency gains for hybrid vehicles compared with conventional cars. However, for some hybrid vehicles in service, the actual gains have been rather modest.

This discrepancy can be explained by various factors, notably the type of use, since the benefits of hybrid electric vehicles are much greater in city driving than on the highway. However, the key factor is the design of the vehicle itself. Unfortunately, the higher efficiency of the hybrid design can be used to increase acceleration capacity rather than to reduce fuel consumption. As a result, some hybrid vehicles with a small four-cylinder engine have better acceleration than ones with a six-cylinder engine, but provide only a modest decrease in fuel consumption.

Moreover, a hybrid system can be installed in a large, heavy SUV, which leads to high fuel consumption regardless of the design.

Consequently, it cannot be assumed that hybrids always have low fuel consumption. Looking at official fuel consumption ratings remains essential when choosing a vehicle.

Producing hydrogen from clean electricity?

Recognizing that hydrogen produced from natural gas does not reduce GHG emissions, some advocates of the *hydrogen economy* propose that hydrogen should be obtained by water electrolysis (the splitting of water to produce hydrogen) using a source of clean electricity such as wind power. A "wind power + hydrogen production and compression + fuel-cell" cycle would indeed be very low in GHG emissions.

We must, however, ask the following question: if it is possible to generate large additional amounts of electricity from clean options such as wind or hydro power, should we use this electricity to produce hydrogen? When we compare potential uses of this clean energy, the answer is clearly no. One kWh of clean energy used to replace coal-fired generation provides GHG emission savings of about 1,000 grams, compared with a reduction of only about 380 grams when used to replace petroleum fuel through the hydrogen fuel cell route.

In this context, the environmental priority should be to replace coal, as long as coal is still being used to generate electricity. The hydrogen economy will only be environmentally justified when coal-fired generation has been completely phased out (or technologies to capture and sequester CO_2 from coal plants have been implemented at all remaining plants). Considering that the cost of fuel cells is still at least 10 times greater than the cost of conventional engines, it is not realistic to expect the *hydrogen economy* before another 40 or 50 years (and only in a scenario where oil and gas are no longer available as major energy sources for transportation).

Conclusions

- In an urban context, public transit options (subways, electric trams, and trains and buses) are, and will remain, the most efficient options. Their performance appears even better when the indirect energy consumption of personal transportation (oil refining, car manufacturing, road maintenance, etc.) is taken into account.
- Among personal transportation options, it is possible to reduce GHG emissions by 50%, simply by encouraging the use of more efficient conventional vehicles.
- Hybrid electric cars, which are already commercially available, can provide additional emission reductions. But this technology can be used to increase acceleration rather than reduce fuel consumption. Consulting official fuel consumption ratings remains essential when choosing a vehicle.
- Battery-powered electric vehicles are extremely efficient but have a limited range. In many specific applications, they can reduce emissions. Reductions can also be achieved by charging hybrid electric vehicles overnight (in regions where electricity is not produced by coal).
- Concerning intercity transportation, a serious discussion is required to define the proper role of air transport. This issue is complex because practical alternatives to long-distance air travel often do not exist. However, the use of airplanes for short distances could be replaced by much more efficient options, such as modern trains.
- Expectations concerning fuel cells and the hydrogen economy are not realistic. In fact, they are often a hindrance, because they can be used to justify the absence of effective short-term measures, on the assumption that a miraculous future option will eventually solve all problems.

The environmental priority should be to replace coal, as long as coal is still being used to generate electricity.

The most important conclusion to be drawn is probably as follows: numerous reliable options exist to reduce GHG emissions by 50% in the transportation sector and there is no need to wait for new technologies.

Table 3: Transportation options – Energy consumption and CO_2 emissions				
Mode	**Number of passengers, or load factor**	**Consumption (kJ per passenger-km)**	**Energy source**	**Direct** CO_2 emissions (g per passenger-km)**
Intercity passenger transportation				
SUV 12 litres/100 km	one	4,200	gasoline	286
Mid-size car: 8 litres/100 km	one	2,800	gasoline	190
Compact car: 6 litres/100 km	one three	2,100 800	gasoline	143 54
Diesel bus	average*	567	diesel	40
Train: Diesel (LRC) Electric	50% 50%	800 300	diesel hydro	56 0
Airplane: Flight of more than 1,000 km Domestic flight	average	1,500-2,500 3,000-5,000	kerosene kerosene	102-170 204-340
Snowmobile on trail	one	4,000-9,200	gasoline	272-626
Urban passenger transportation				
SUV: 17 litres/100 km	one	5,950	gasoline	405
Mid-size car: 12 litres/100 km	one	4,200	gasoline	286
Compact car: 9 litres/100 km	one three	3,150 1,100	gasoline	214 75
Diesel bus	50% 100%	800 450	diesel diesel	56 32
Electric tram	100%	300	hydro	0
School bus	average	432	gasoline	29
Subway (electric)	40% 100%	280 130	hydro	0
Pedestrian		150	cereals	wheat = 2
Cyclist		60	cereals	wheat = 1
Freight transportation	**Load factor**	**kJ per tonne-km**	**Energy source**	**g per tonne-km**
Diesel truck: all heavy	average	1,583 600-1 000	diesel diesel	111 42-71
Train	100%	280-400	diesel	20-28
Ship	average	less than 200	oil	less than 14
Pipeline	average	170		
Cargo plane	average	7,000-15,000	kerosene	476-1,020

* Average = load factor based on average from actual data.

** Estimates of CO_2 emissions do not include emissions related to fuel refining, vehicle manufacture or infrastructure construction.

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